Covariance Matrix Evaluation for ^{235}U

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Motivation

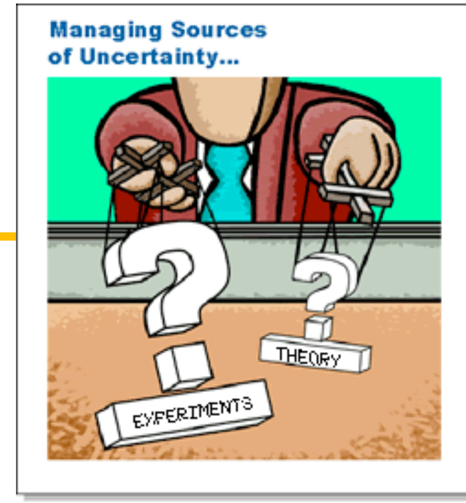
- The idea of Uncertainty Quantification (UQ) is not new in nuclear data evaluation (e.g., adjustment of cross sections on integral data). However, it has rarely made it to ENDF files.
- Sensitivity studies by Palmiotti, Aliberti et al. have proven to be very useful for directing experimental and evaluation efforts for specific uses (AFCI and GEN-IV).
- Such studies need carefully evaluated uncertainties on certain isotopes and reactions.
- First isotopes being studied: ^{235}U, ^{238}U and ^{239}Pu.

Where does uncertainty come from?

- Experiments:
  - Statistical and systematic errors happen in any experiment. Accounting for them carefully can be a challenge.
- Theory:
  - Nuclear reaction calculations use various models to describe different aspects of a nuclear reaction. Uncertainties occur not only in the model input parameters, but in the models themselves.
- Evaluation:
  - Evaluated cross sections are the result of experimental data and model calculations.

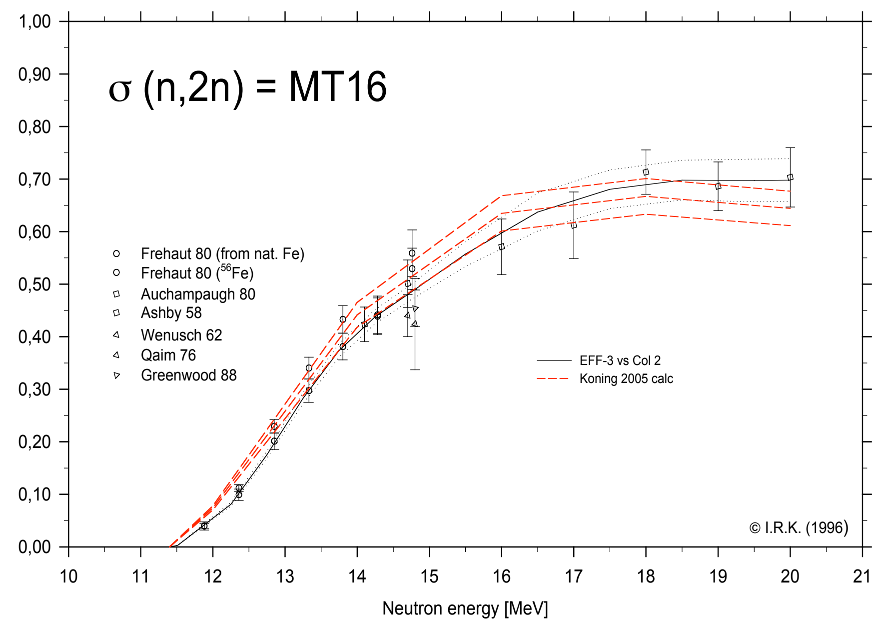
What type of uncertainties?

- Statistical: relatively easy to handle (generally small in today's experiments).
- Systematic: most problematic- give birth to correlations (e.g., sample impurities)
- Models: strong correlations due to the underlying physics model.
- Model input parameters: commonly adjusted to experimental data. Uncertainties are now estimated by comparison with accurate experimental data (e.g., RIPL3 IAEA effort)



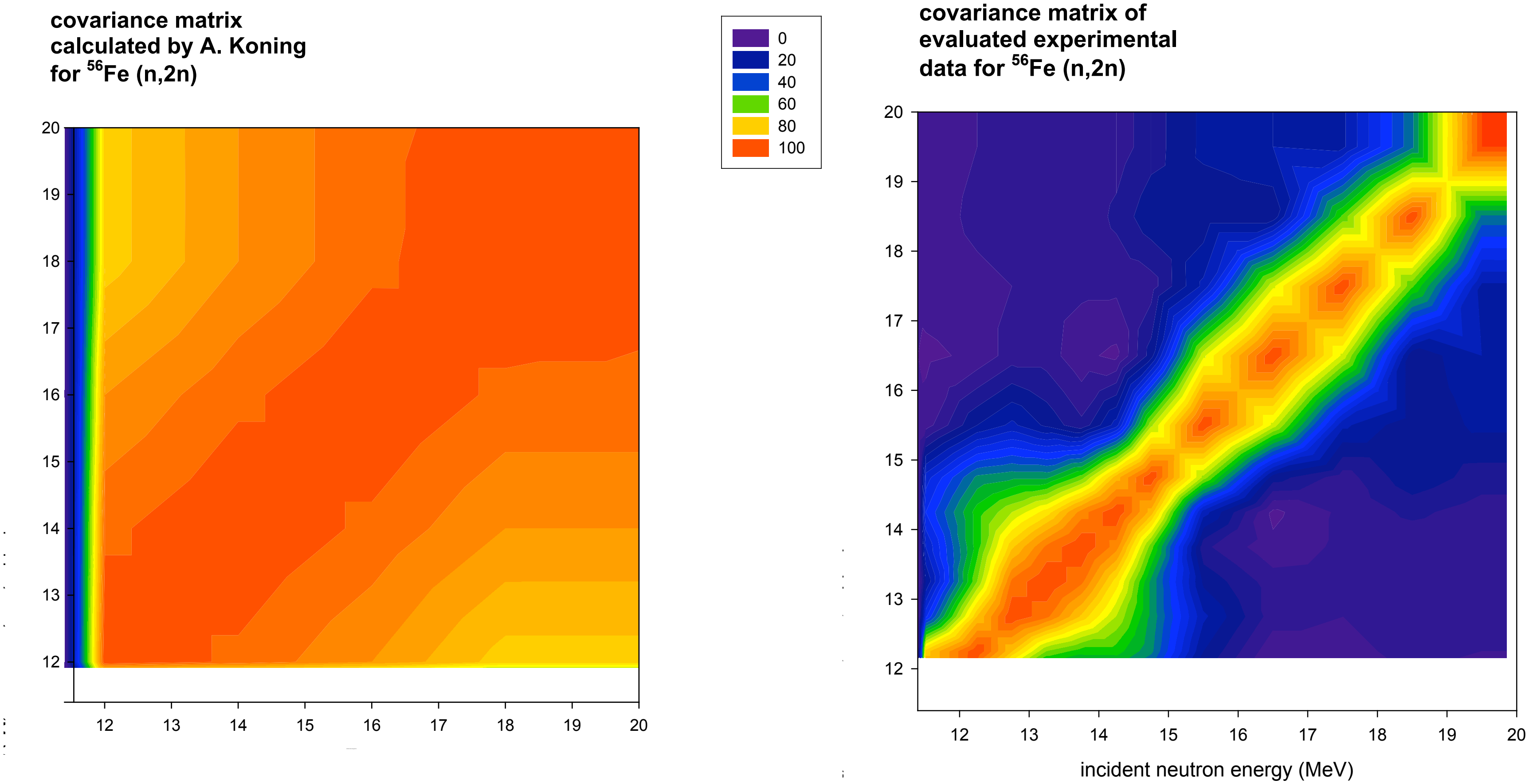
Tagesen, Vonach, JEFF Meeting (Nov. 2005)

^{56}Fe, Comparison of EFF-3, experimental data and blind calculation with TALYS



Model calculations vs. Experimental data

Tagesen, Vonach, JEFF Meeting (Nov. 2005)



Uncertainty Quantification for AFCI/Gen-IV

1) Gather available experimental data for particular isotopes and reactions. Evaluate the individual covariance matrices.
2) Assemble a global experimental covariance matrix through a Bayesian inference scheme.
3) Perform nuclear reaction calculations, and infer a sensitivity matrix to the model input parameters.
4) The experimental and model covariance matrices are combined (Kalman filtering) to get the final covariance matrix.
5) This covariance matrix is processed through NJOY/ERRORJ in order to obtain a matrix in the 17 energy-group structure used in sensitivity studies.

Tools

- Code to retrieve experimental data from the EXFOR database and build cross section and covariance matrix files used in Step #2.
- The SOK code has been used for the Bayesian evaluation of experimental data sets.
- We have put in place the KALMAN+GNASH coupling in order to calculate the sensitivity matrix to model input parameters. (Tested on ^{89}Y and ^{241}Am for a limited number of reaction channels so far).Still need to develop more automatic setup for building this covariance matrix.
- ERRORJ and NJOY ready for processing our covariance matrices.

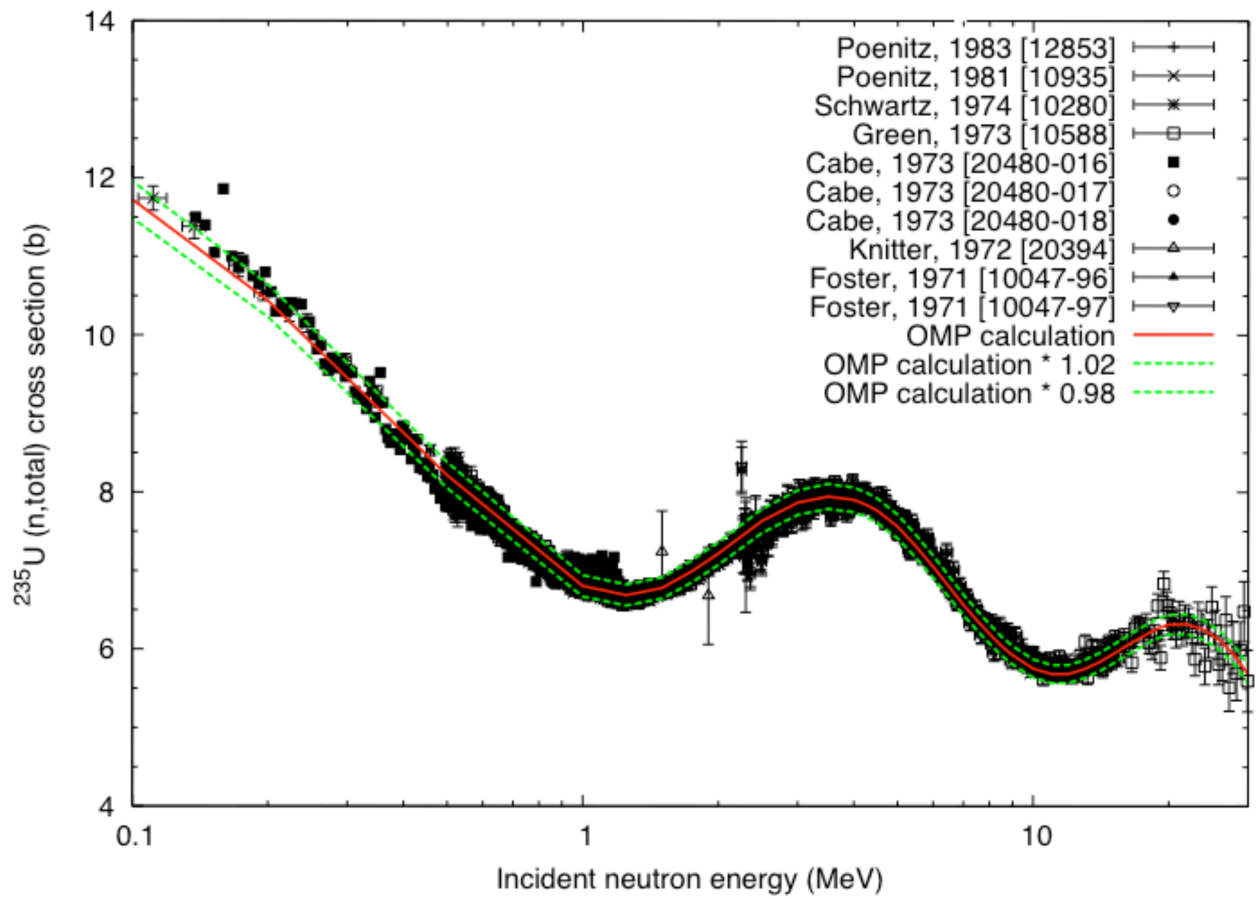
Preliminary Results for ^{235}U

- Neutron-induced reactions on ^{235}U
- Energy range: 0.1 to 30 MeV
- Extension below 100 keV with ORNL work for Criticality / Safety program ; extension above 30 MeV by experimental data evaluation mostly.
- Cross sections of interest: (n,total), (n,fission), (n,inel), (n,g), (n,2n), (n,3n)
- Other quantity of interest: <n> number of prompt fission neutrons

^{235}U (n,total) cross section

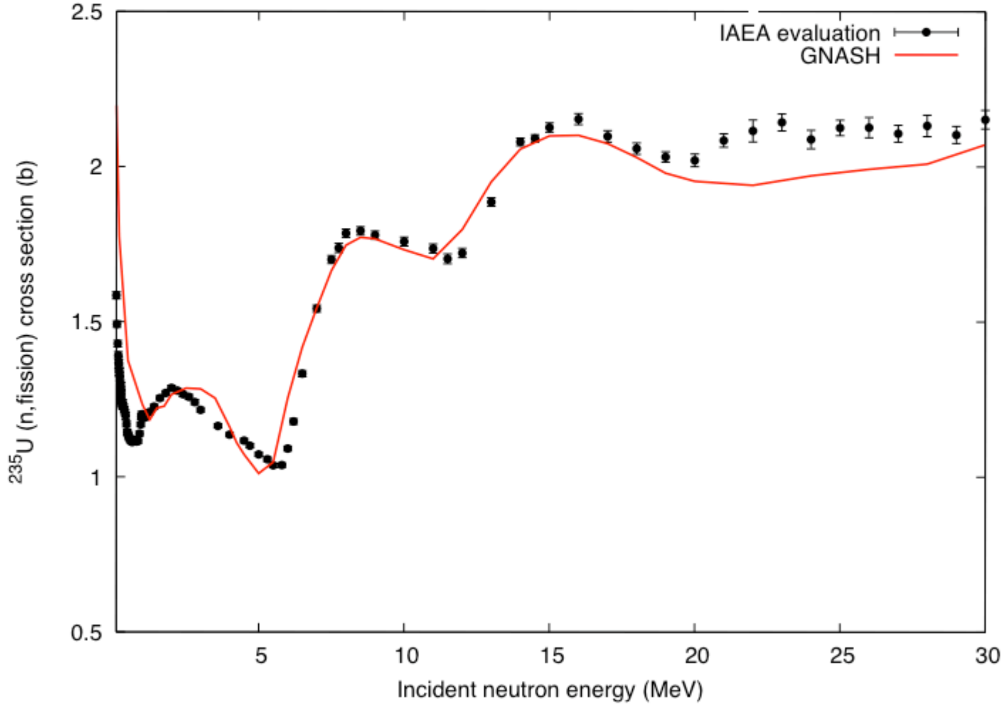
Used to constrain partial reaction channels.

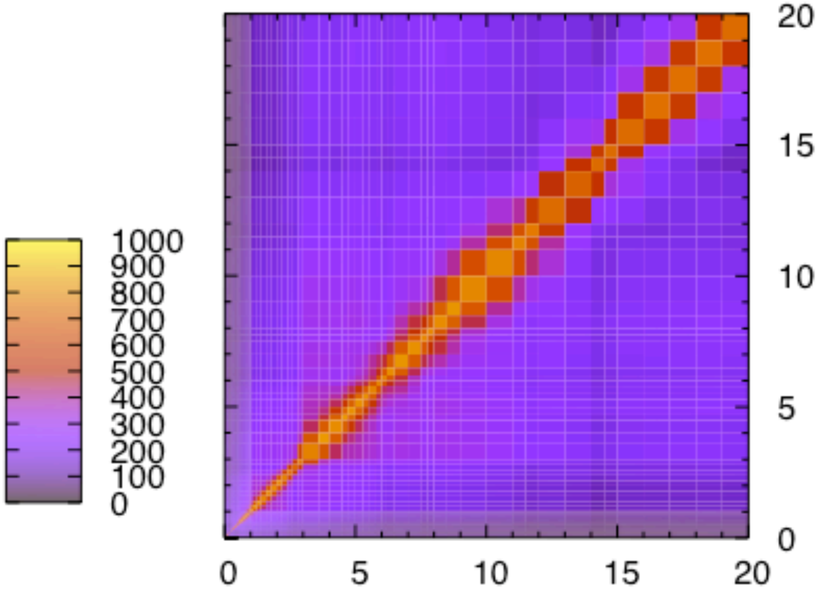
Known to 1-2%.



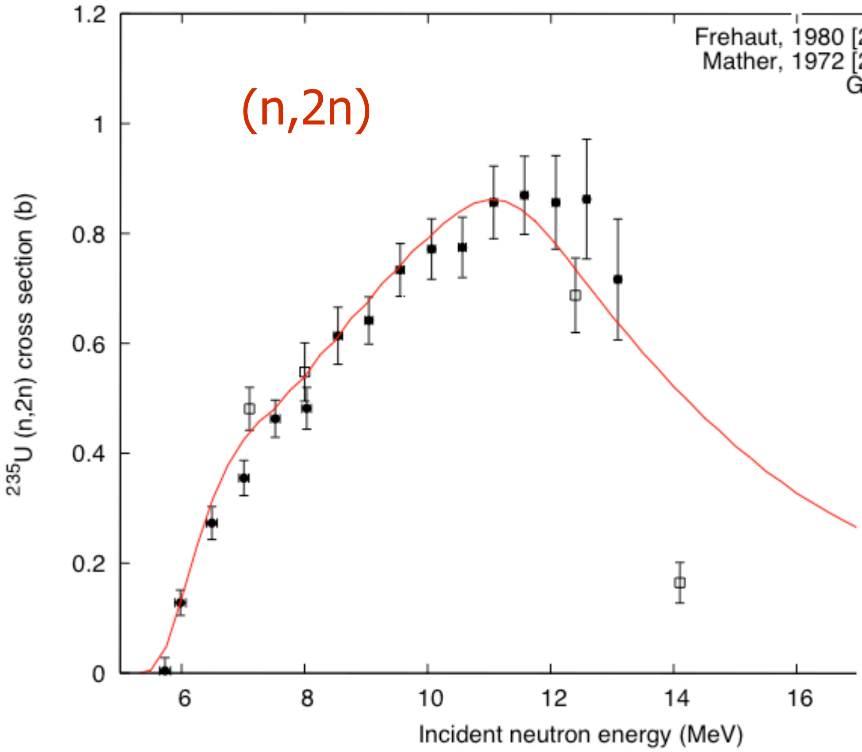
^{235}U (n,fission) cross section

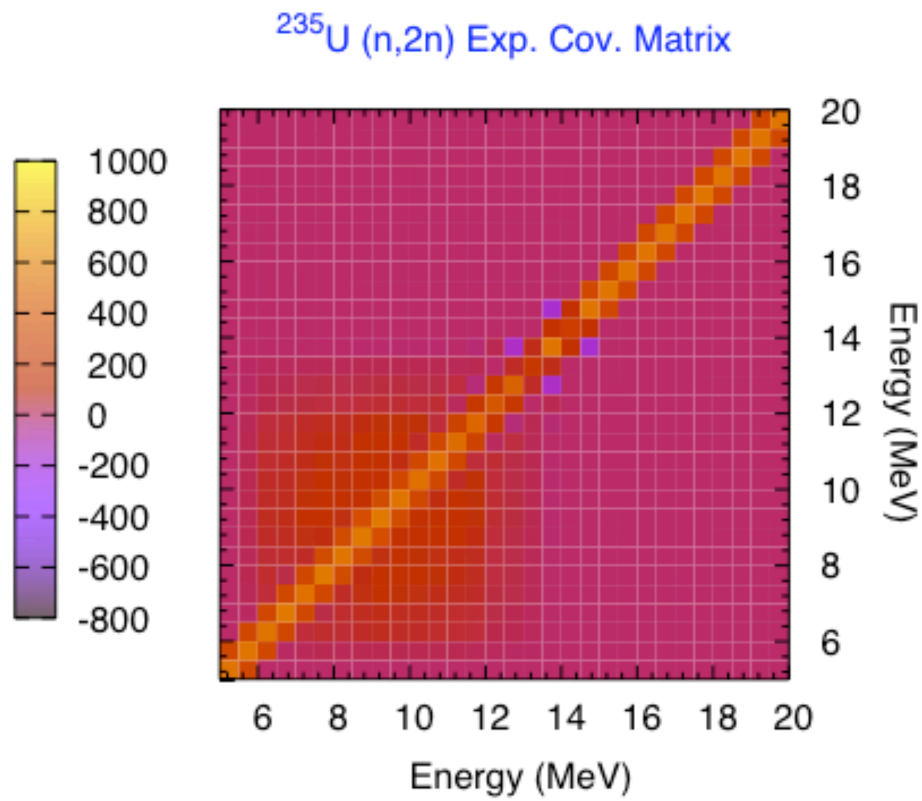
IAEA Coordinated Research Program on "standards" evaluation (2005)



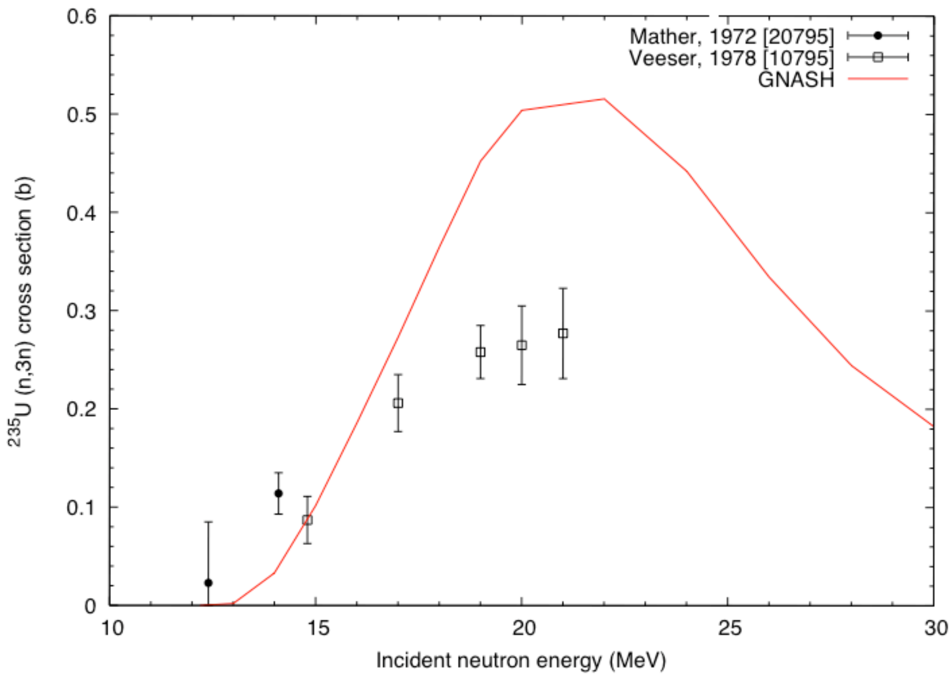


(n,2n) channel

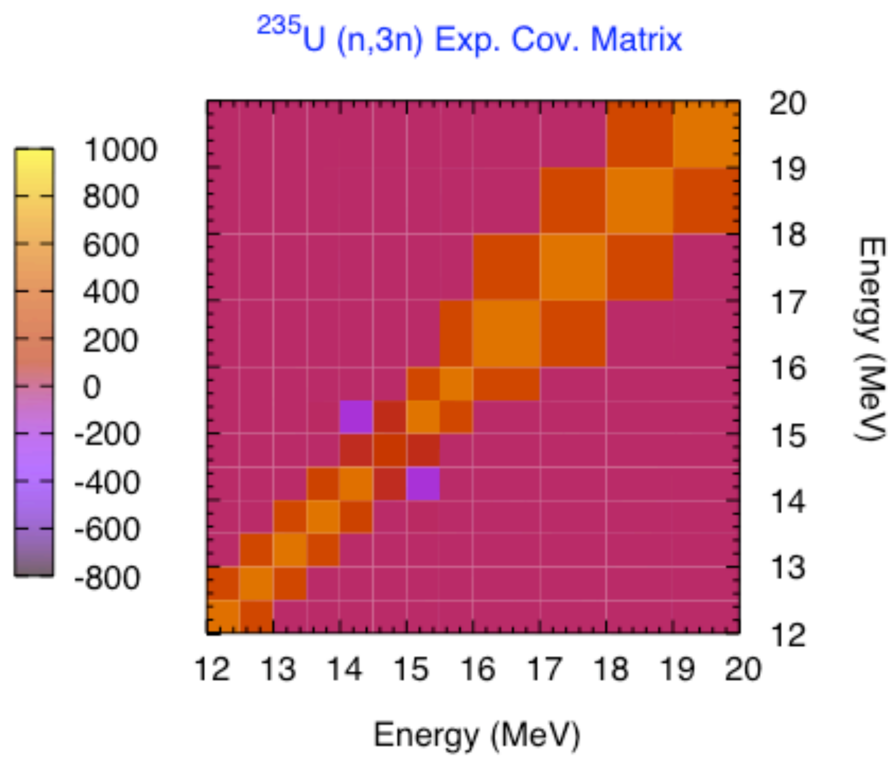

Frehaut, 1980 [21568]
Mather, 1972 [20795]
GNASH
(n,2n)
^{235}U (n,2n) cross section (b)
Incident neutron energy (MeV)
0
0.2
0.4
0.6
0.8
1
1.2
6
8
10
12
14
16


^{235}U (n,2n) Exp. Cov. Matrix
1000
800
600
400
200
0
-200
-400
-600
-800
Energy (MeV)
Energy (MeV)
6
8
10
12
14
16
18
20

(n,3n) channel



Mather, 1972 [20795]
Veeser, 1978 [10795]
GNASH
^{235}U (n,3n) cross section (b)
Incident neutron energy (MeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
10
15
20
25
30



^{235}U (n,3n) Exp. Cov. Matrix
1000
800
600
400
200
0
-200
-400
-600
-800
12 13 14 15 16 17 18 19 20
Energy (MeV)
Energy (MeV)

Progress Status for ^{235}U

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